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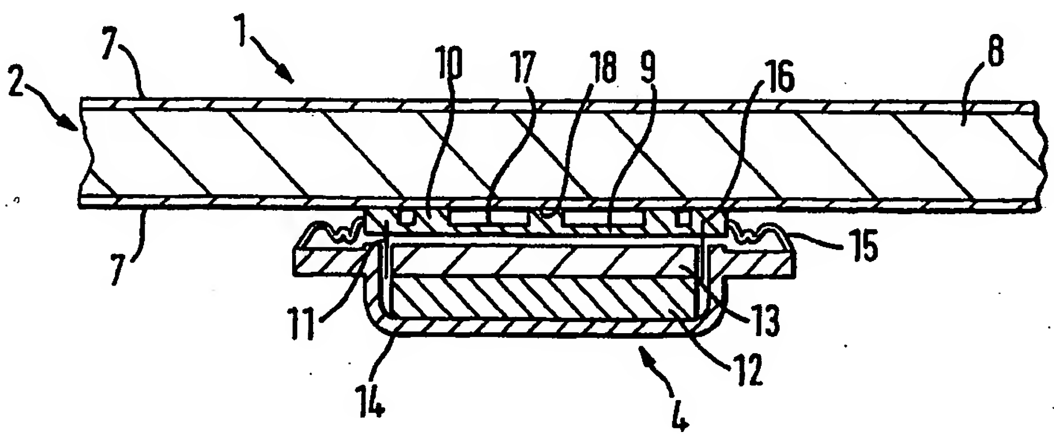


(57) Abstract

A vibration exciter or transducer (4) for imparting bending wave energy to a resonant panel (2), wherein the exciter (4) is adapted to be coupled to the panel at a plurality of discrete positions (6) forming a triangular array.

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# VIBRATION TRANSDUCERS FOR RESONANT PANEL-FORM LOUDSPEAKER AND LOUDSPEAKER WITH THE SAME

## DESCRIPTION

## TECHNICAL FIELD

The invention relates to loudspeakers. More particularly, but not exclusively, the invention relates to electrodynamic vibration exciters for resonant panel-form loudspeakers of the kind in which bending wave energy is imparted to the resonant panel to produce an acoustic output. Such loudspeakers are described in our International application WO97/09842.

A vibration exciter for exciting a resonant loudspeaker panel needs a form of fixture onto the panel surface allowing the best possible conversion of driver power into bending waves. An inertial reaction exciter applies a push/pull force to the panel by reacting against the inertia of the exciter mass. Only the motor element is

rigidly attached to the panel and the ideal fixture where the panel has a cellular core and skin layers is a small single position contact that is larger than the cell size of the panel core and with a stronger attachment than the core-to-skin bond strength of the panel.

## BACKGROUND ART

An already proven system of construction bonds the tubular voice coil assembly directly to the panel skin to make a strong circular contact with the panel. The resultant large contact area under the voice coil is, however, effectively reactive at higher frequencies which limits the power input to the panel as the modal dimensions approach the size of the circular contact area.

It is an object of the invention to mitigate such problems

## DISCLOSURE OF INVENTION

According to the invention there is provided a vibration exciter for imparting bending wave energy to a resonant panel to provide an acoustic output, wherein the exciter is adapted to be coupled to the panel at a plurality of discrete positions forming a triangular array of contact patches. The discrete coupling positions may be spaced round a circle which may conveniently correspond to the end shape of a conventional tubular voice coil former.

The discrete coupling positions may be created by notching or castellating the end of the voice coil former or may be formed by a mounting member to which the voice coil is attached. The effect of this is that the contact

area is reduced and the originally enclosed circumference contact is opened to allow distributed mode bending waves in the panel to pass under the exciter area. A significant consequence of this is that the exciter 'sees' a resistive mechanical load extending to higher frequencies.

The most mechanically stable configuration is three equally spaced castellations and this is confirmed by mathematical modelling. Changing the contact patch shape from segments of circumference to straight lines further increases the modal input to the panel. For convenience, generally circular contact patches may be employed.

The above description teaches the principle of discontinuous contact using a moving coil vibration exciter as the example. The same principle might, however, be applied to any form of vibration exciter, with an interrupted or discontinuous form of physical connection between the drive element and the panel.

Additional contact between the exciter and the panel may be provided by a centrally disposed diametrically extending member, e.g. of cruciform shape, positioned within the basic triangular array.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figure 1 is a partial view of a prior art resonant panel loudspeaker and showing the area of the mounting or connection between a vibration exciter and the resonant panel;

Figure 2 is a partial view generally similar to that of Figures 1 and illustrating a first embodiment according to the invention;

Figure 3 is a cross-sectional side elevation of a vibration exciter attached to a resonant panel and corresponding to Figure 2;

Figure 4 is a view generally similar to that of Figure 1 and illustrating a second embodiment according to the invention;

Figure 5 is a view generally similar to that of Figure 1 illustrating a third embodiment according to the invention, and

Figure 6 is a cross-sectional side elevation of a vibration exciter attached to a resonant panel and corresponding to Figure 5.

In Figure 1 of the drawings, there is shown an acoustic device (1) of the kind described in International patent application WO97/09842, comprising an acoustic member (2) in the form of a resonant panel to which bending wave energy is applied by a vibration exciter (not shown) to cause the panel (2) to resonate to produce an acoustic output. As described in WO97/09842, the vibration exciter may comprise a moving coil electrodynamic motor having a voice coil directly attached to a face of the panel (2). Annulus or ring (3) is intended to represent the contact area or 'footprint' of the voice coil, or at least the tubular former on which the coil is wound, on the face of the panel (2). We have found that this method of

attachment, which is intended to maintain the inertia of the voice coil at a minimum in the interests of efficiently transmitting bending wave energy to the panel, introduces a secondary effect, which we know as the "aperture effect" in which maximum frequency response of the panel is related to the diameter of the ring or annulus (3) formed by the joint between the exciter and the panel (2). We have identified another, at least potential, effect in which the portion of the panel within the ring or annulus (3) can exhibit a secondary resonance, which we know as the "cap" resonance.

The present invention seeks at least to mitigate occurrence of the aperture effect and/or cap resonance.

## BEST MODES FOR CARRYING OUT THE INVENTION

Referring now to Figures 2 to 6 of the drawings, and more particularly to Figures 2 and 3 of the drawings, the present invention provides mounting arrangements for vibration exciters (4) (see Figures 3 and 6) on resonant panels (2) such that the resonant behaviour of the panel (2) is not interrupted or is less so than is the case with the mounting footprint of the arrangement of Figure 1.

Thus Figure 2 shows a contact area or footprint for an exciter on the panel in the form of a circular array (5) of discrete contact patches (6). The basic requirement for stability is met by three contact patches forming a triangle, but in the present embodiment there are eight contact patches for increased strength. From Figure 3 is will be seen that the exciter (4) is an inertial device of

the general kind shown in Figure 11b of International patent application WO97/09842 and has a voice coil (11) comprising a coil wound on a cylindrical former, one axial end of which voice coil (11) being drivingly mounted on the panel (2) to impart bending wave energy into the panel, and a magnet assembly (12,13,14) surrounding the voice coil (11) and comprising a magnet (12) sandwiched between a pole piece (13) which fits inside the voice coil (11) and a second pole piece (14) in the form of a cap which surrounds the voice coil, the magnet assembly and the voice coil being connected by a resilient suspension (15) which also serves the function of a dust excluder.

An axial end (16) of the voice coil (11) is supported on the panel in a generally annular mounting member (9) which may be a plastics moulding. The end (16) of the voice coil may be attached to the mounting member (9) by means of an adhesive or alternatively the mounting member may be directly moulded onto the voice coil. A side (17) of the mounting member facing away from the exciter (4) is formed with a series of short castellations or projections (10) extending away from the side (17) and disposed to form an annular array, the end faces (18) of the castellations (10) forming the array of discrete contact patches (6) which together define the footprint of the exciter (4) on the panel (2). The exciter may be secured to the panel by means of adhesive applied to the end faces (18) of the mounting member (9).

The embodiment of Figure 4 is generally similar to

that of Figures 2 and 3 with the exceptions that the number of discrete contact patches (6) in the array (5a) is increased and in addition the area defined by the circular array (5a) is occupied by a centrally disposed additional contact (19) in the form of a cross member in the interests of improving the coupling between the exciter and the panel. The cross shape of the contact (19) is chosen since it is radially discontinuous, that is to say it does not form a closed figure and thus does not substantially adversely affect the bending wave behaviour of the panel as may be the case with the continuous ring footprint of Figure 1.

Figures 5 and 6 show an alternative embodiment of the invention which is very similar to that of Figures 2 and 3 as modified by the embodiment of Figure 4. In the present case the contact array (5b) is modified in that the solid cross-like additional contact (19) of Figure 4 is replaced by a cross-like array (20) of discrete contact patches (21), further to reduce any interference to the bending wave behaviour of the resonant panel (2) due to the exciter mounting.

## INDUSTRIAL APPLICABILITY

Division of the driving contact is thus a means for improving termination of the mechanical junction between the exciter and the panel. It may be adjusted by design to tune the upper frequency properties of the panel radiation to match the characteristics of the panel chosen. Thus simple castellation may be chosen to couple from as few as

three points with a contact area sufficient to reliably bond the exciter to the panel surface. Different configurations of contact geometry provide further scope for fine tuning this interface where in some cases the several factors of contact area, glue bond, panel loss, aperture effect and cap resonance may interact with each other.

Although not shown in the drawings, it will be appreciated that instead of mounting the voice coil on the panel <u>via</u> a castellated mounting member (9), it might be possible instead to mount the voice coil directly on the panel while still achieving the benefits of this invention. In this case it would be necessary to castellate or otherwise adapt the end of the voice coil former to provide a ring of discrete mounting positions. Possibly the ends of the castellations could be folded to form flanges to increase the area of contact as a strengthening aid when adhesively fixing the voice coil to the panel.

The invention thus provides a simple method of reducing aperture and/or cap effects in fixing vibration exciters to resonant panels. While the invention has been particularly described with reference to moving coil exciters, it will be appreciated that the method can be applied also to other (non-voice-coil) type exciters to achieve the same benefits.

## CLAIMS

1. A vibration exciter for imparting bending wave energy to a resonant panel, wherein the exciter is adapted to be coupled to the panel at a plurality of discrete positions forming a triangular array.

2. A vibration exciter according to claim 1, wherein the array comprises more than three discrete positions located on the circumference of a circle.

3. A vibration exciter according to claim 1 or claim 2, comprising at least one additional coupling position centrally positioned within the triangular array.

4. A vibration exciter according to claim 4, wherein the additional coupling position is cruciform in shape.

5. A vibration exciter according to claim 4, wherein the cruciform shape comprises an array of discrete coupling positions.

6. A vibration exciter according to any preceding claim, comprising a mounting member formed with projections defining the discrete coupling positions.

7. A vibration exciter according to claim 6, wherein the mounting member is annular in shape.

8. A vibration exciter according to claim 6 or claim 7, comprising a moving coil electrodynamic motor, and wherein the mounting member is attached to the voice coil.

9. A vibration exciter according to any preceding claim, wherein the exciter is an inertial device.

10. A loudspeaker comprising a vibration exciter as claimed in any preceding claim.

11. A loudspeaker according to claim 10, comprising an acoustic member in the form of a resonant panel.

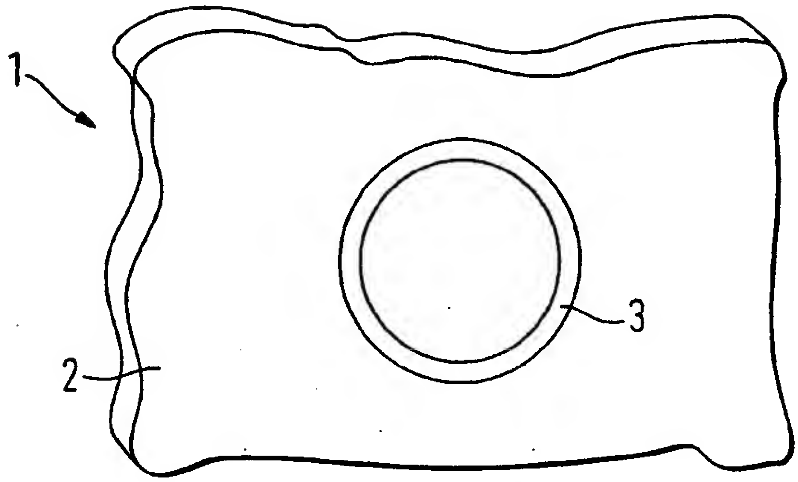


FIG. 1
PRIOR ART

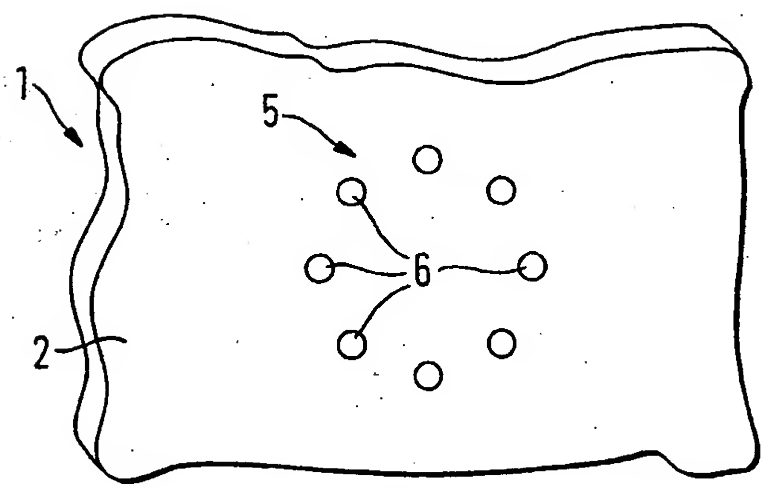


FIG. 2

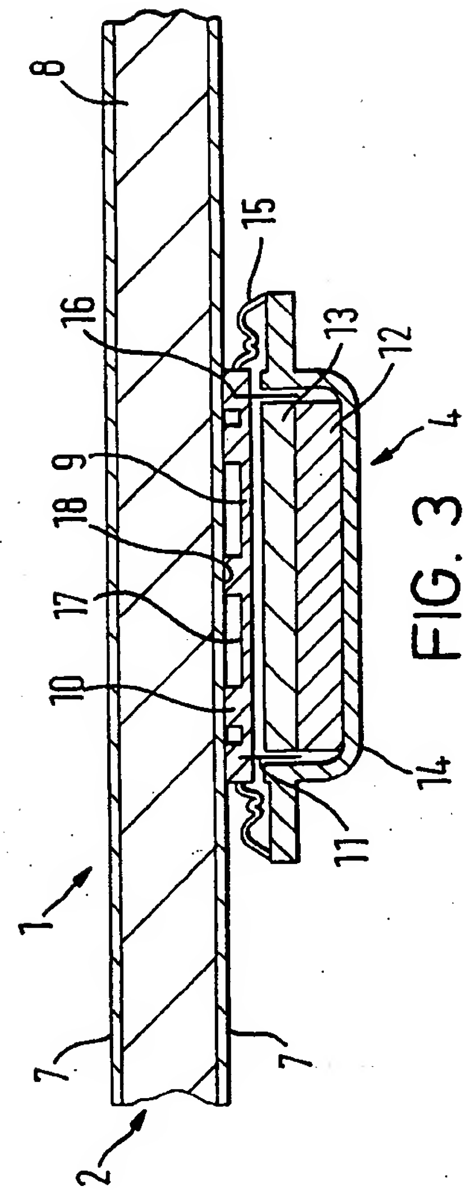


FIG. 3

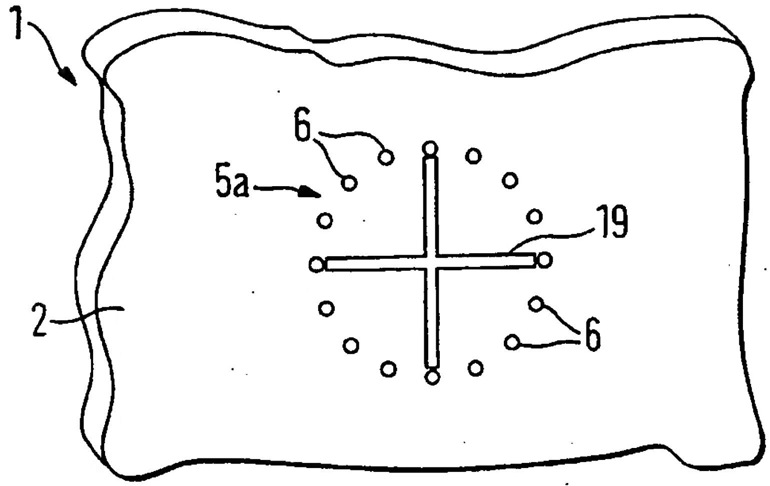


FIG. 4

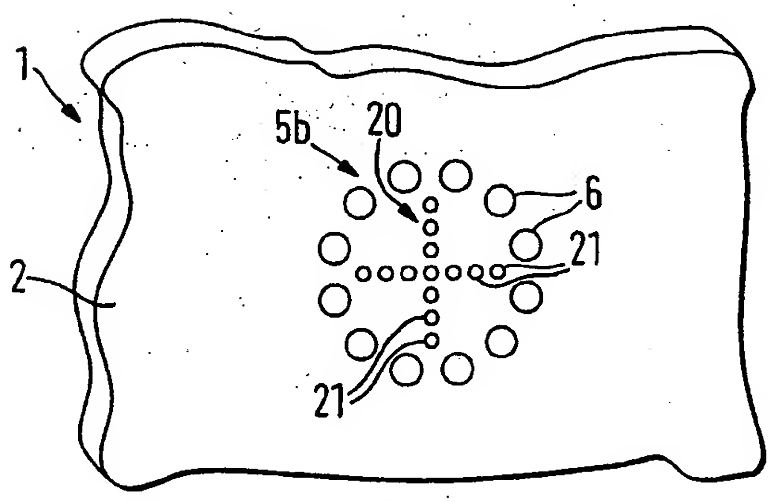


FIG. 5

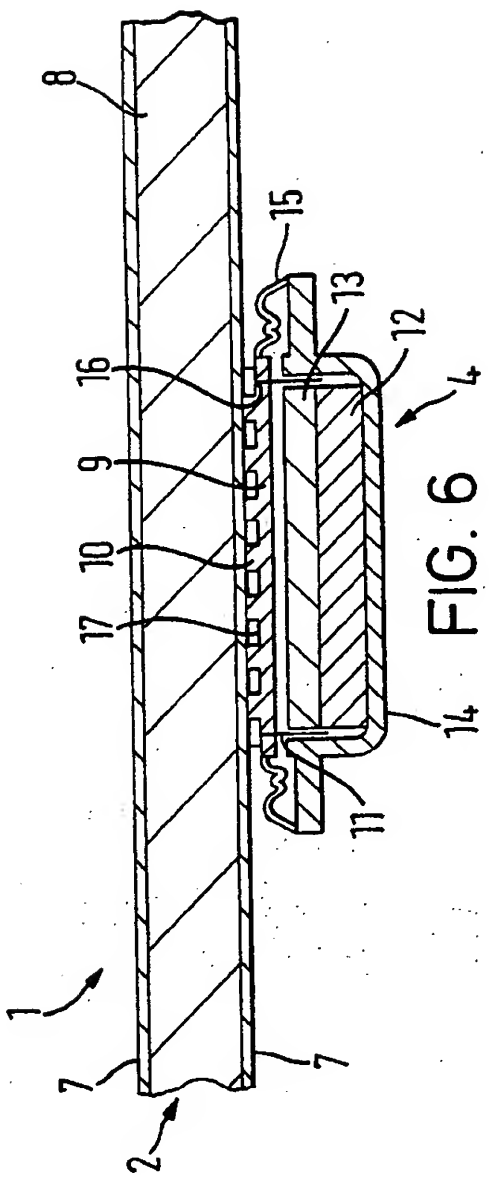


FIG. 6